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EP 0512718 A1 EP 0311418 A2 EP 0134556 A1
WO 94/22281 A1 US 5055816 A

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INT CL^6 H01F 17/00 17/04 27/28 41/04 , H03H 1/00 7/00 7/09 , H05K 1/00

(54) Electronic device comprising an inductive via

(57) An electronic device 10 comprises an inductor formed by a via 22a or 22b. The device 10 may comprise a substrate 12 formed as one layer, or a laminate 14 of plural layers 14a-h, which may be formed by an insulating, magnetic or ceramic material. The device 10 may have one or more inductive vias 22a, 22b formed with a round or square cross-section. The inductive vias 22a, 22b may be disposed in a certain arrangement relative to other formations, such as capacitive, ground 20a, 20b and electrode plates, built into the device. The device may be used in forming one or more resonators or LC filter arrangements.

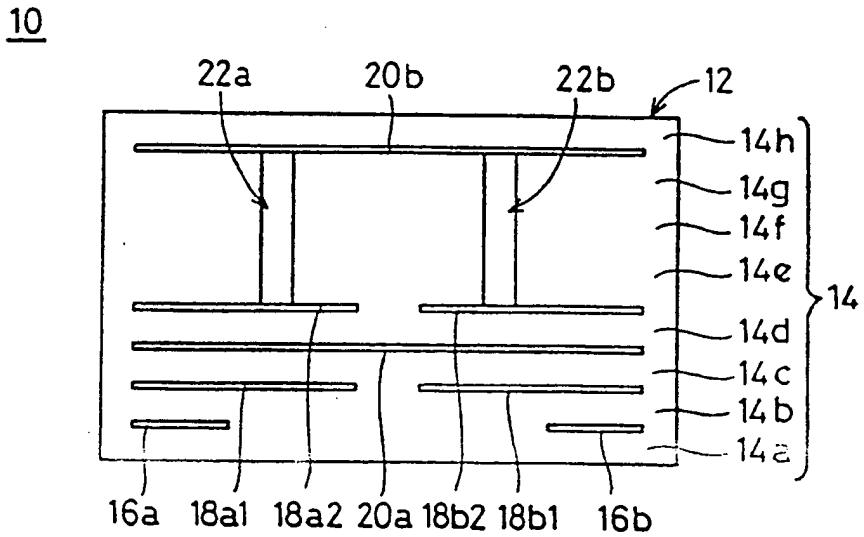

FIG.1

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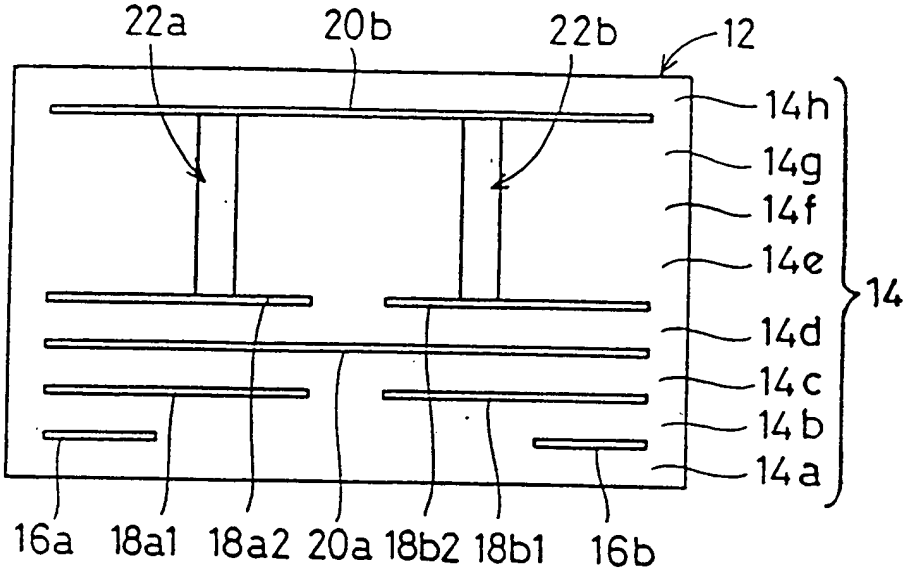

FIG. 1

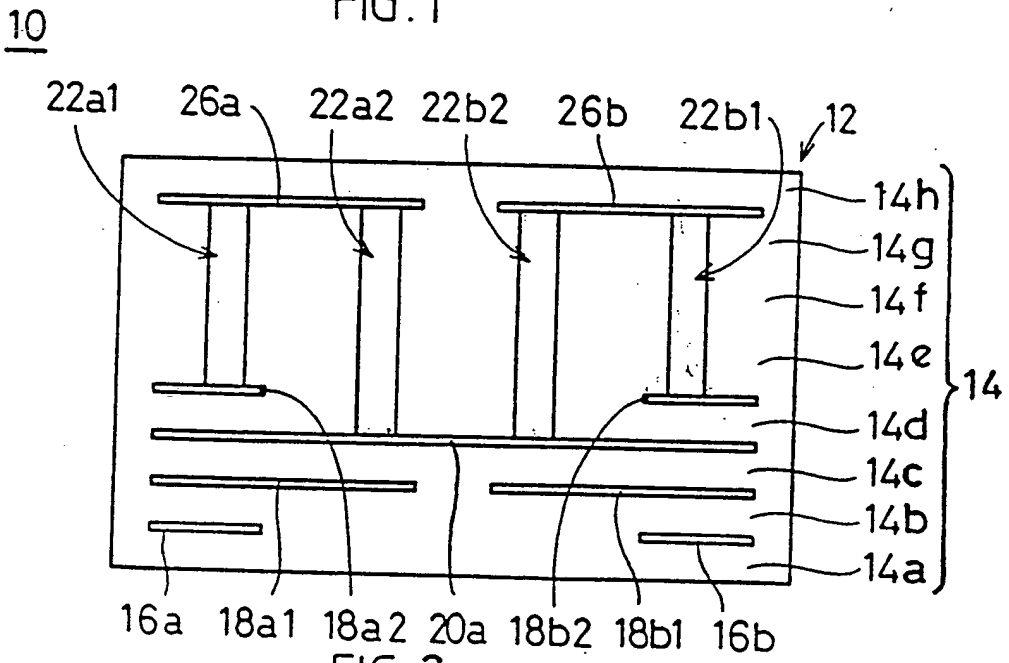

FIG. 2

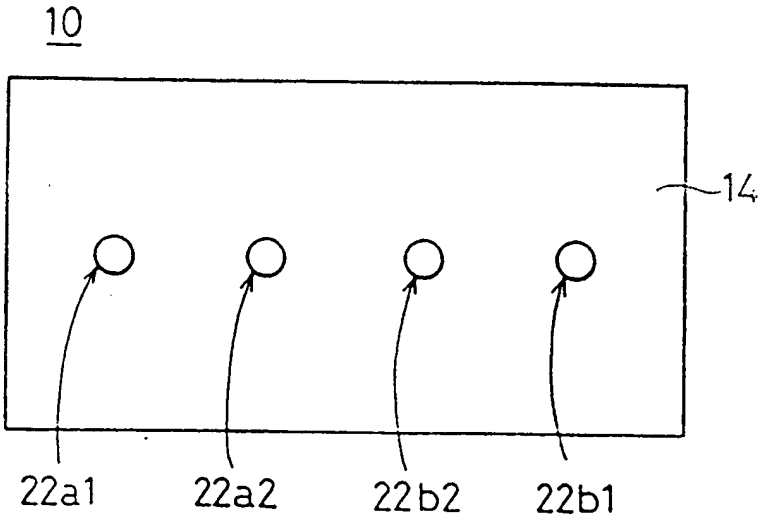

FIG. 3

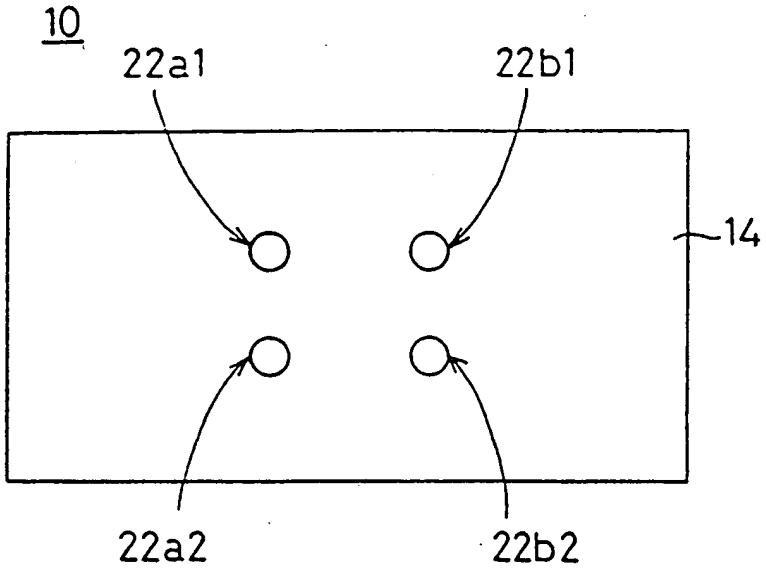

FIG. 4

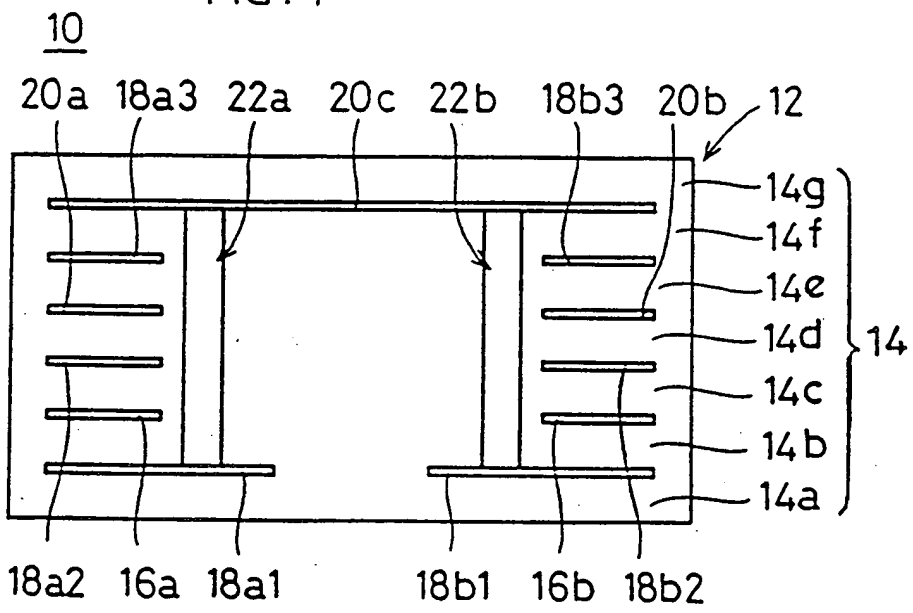

FIG. 5

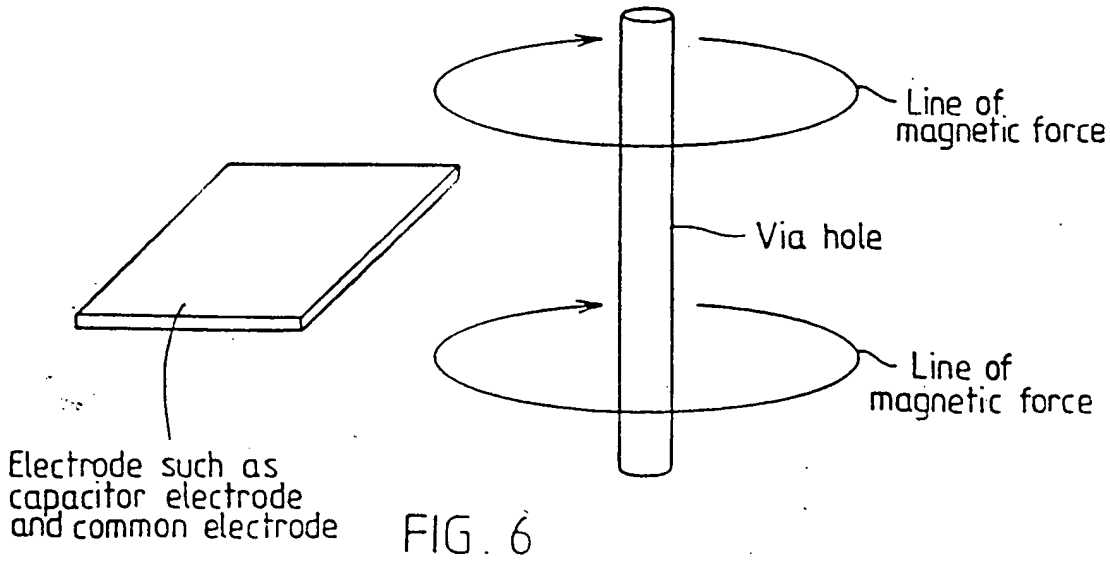

FIG. 6

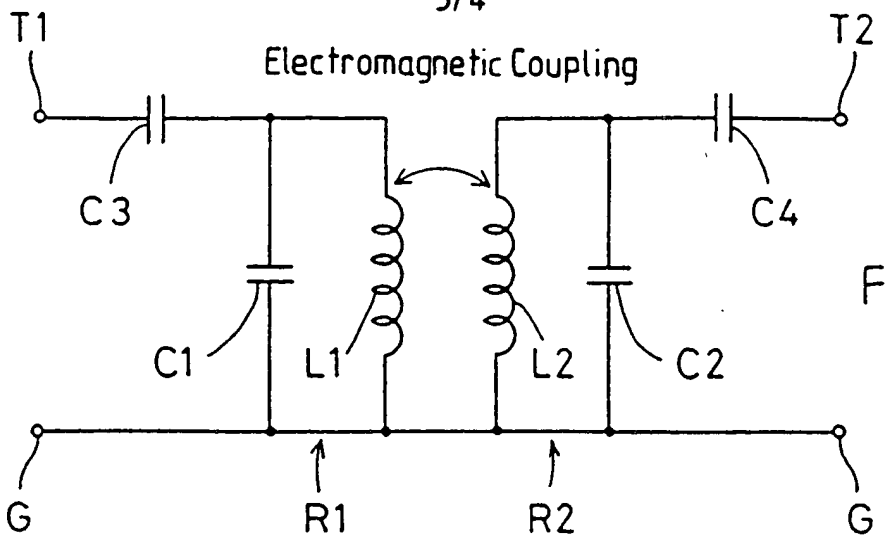

FIG. 7

1

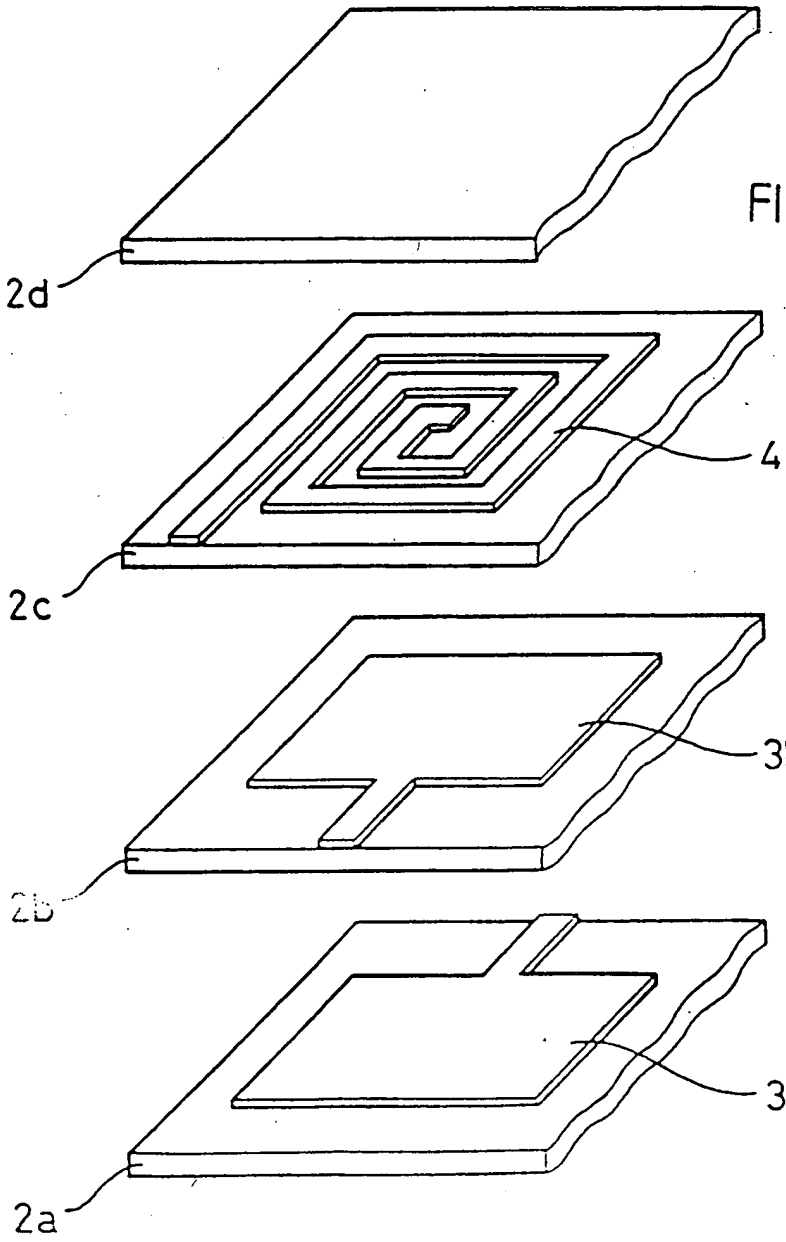

FIG. 8 PRIOR ART

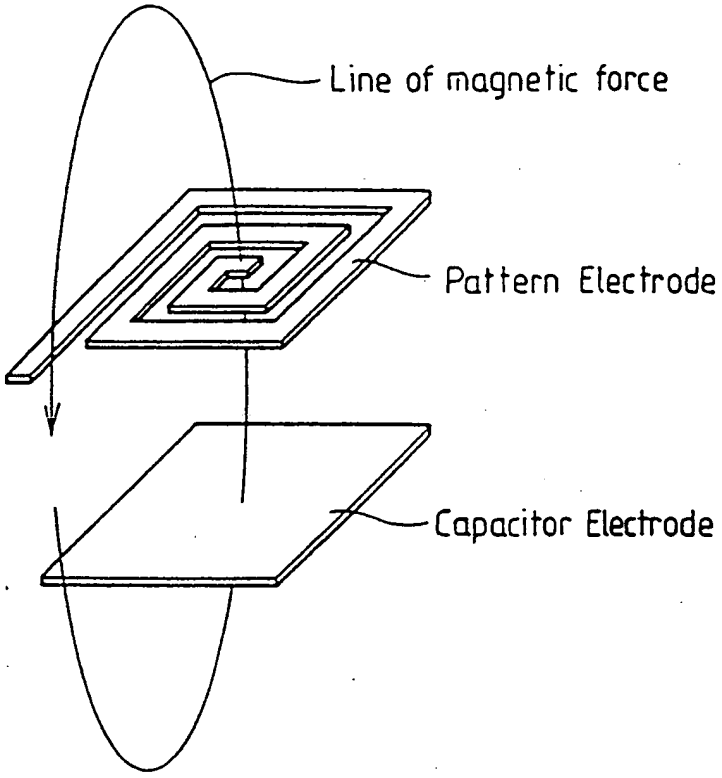

FIG. 9
PRIOR ART

INDUCTOR BUILT-IN ELECTRONIC PARTS

The present invention relates to electronic parts with an integrally built-in inductor and, more particularly, to electronic parts such as an inductor, an LC resonator, band-pass filter and an LC filter for use in a portable radio equipment, for example.

FIG. 7 is an equivalent circuit diagram showing one example of an LC filter acting as a band-pass filter to which the present invention can be applied. The LC filter includes two LC resonators R1 and R2. One LC resonator R1 comprises a first inductor L1 and a first capacitor C1 connected in parallel, and the other LC resonator R2 comprises a second inductor L2 and a second capacitor C2 connected in parallel. It is noted that the first and second inductors L1 and L2 are electromagnetically coupled to each other. One end of the first LC resonator R1 is connected to a first input/output terminal T1 via a third capacitor C3 and one end of the second LC resonator R2 is connected to a second input/output terminal T2 via a fourth capacitor C4. Other ends of the first and second LC resonators R1 and R2 are connected to ground terminals G, respectively.

FIG. 8 is an exploded perspective view showing a main part of the exemplary prior art LC filter having the equivalent circuit shown in FIG. 7. The prior art LC filter 1 shown in FIG. 8 includes four dielectric layers 2a, 2b, 2c and 2d to be laminated together. A first capacitor electrode 3a and the like is formed on the upper surface of the first dielectric layer 2a, a second capacitor electrode 3b and the like is formed on the upper surface of the

the built-in inductor. Therefore, in order to improve the Q of the LC filter 1, it is conceivable to improve the Q of the inductor by increasing a sectional area of the pattern electrode which acts as the inductor element. It is then conceivable to thicken a width of the pattern electrode in order to increase the sectional area of the pattern electrode, because a thickness of the pattern electrode formed by means of thick film printing is only about 10-odd μm. However, the prior art LC filter has had a problem in that when the width of the pattern electrode is thickened, a value of inductance generated by the pattern electrode made within an equal area becomes small and a large floating capacity is generated between the electrodes similar to the capacitor electrodes which vertically face each other. The result is a drop in Q, contrary to the purpose of the design modification. It is noted that this kind of problem also exists in other built-in inductor electronic parts such as prior art inductors and LC resonators in which a pattern electrode acts as an inductor element and is formed by means of thick film printing.

The prior art LC filter 1 shown in FIG. 8 also has had a problem that although the Q of the whole is improved when the space between the pattern electrode and the vertically disposed capacitor electrode is widened, a thickness of the whole, i.e. the size thereof, is increased and it cannot be mounted within small equipment such as portable radio equipment whose thickness is limited. It is noted that this kind of problem also exists in the other inductor built in electronic parts such as prior art LC resonators in which

Further, the inventive built-in inductor electronic parts may be constructed so that capacitor electrodes are formed between the plurality of ceramic layers.

Because the inductors are formed by the via holes penetrating through the plurality of laminated ceramic layers in the thickness direction thereof, a sectional area of the inductor increases, thereby improving the Q of the built-in inductor electronic parts. A size of the built-in inductor electronic parts may be kept small because an area of the main surface and thickness of the ceramic layer need not be increased.

Accordingly, the present invention allows the small built-in inductor electronic parts whose Q is high to be obtained.

It is noted that a value of inductance may be readily controlled in the inventive inductor because a length of the conductor as the inductor is elongated by forming the inductor by the plurality of via holes penetrating through the plurality of laminated ceramic layers in the thickness direction and the value of inductance will not change so much even if the length of the conductor is changed by small amounts, e.g., the variation of thickness among the ceramic layers.

Further, because the main surface of the capacitor electrode is parallel with lines of magnetic force generated by the inductor created by the via hole when forming the capacitor electrodes between the plurality of ceramic layers, less eddy current loss is generated by the lines of magnetic force on the capacitor electrode and the Q will hardly drop.

FIG. 9 is a diagrammatic view showing a relationship between a line magnetic force generated by a pattern electrode and a capacitor electrode in the LC filter shown in FIG. 8.

Preferred embodiments of the present invention will be explained below with reference to the drawings.

FIG. 1 is a diagrammatic view showing one preferred embodiment of the present invention. An LC filter 10 shown in FIG. 1 includes rectangular parallelepiped multi-layered substrates or laminate 12. The laminate 12 is formed by laminating a number of dielectric layers 14a, 14b, 14c, ... made out of a number of ceramic layers.

First and second capacitor electrodes 16a and 16b are formed between the bottom two dielectric layers 14a and 14b leaving a space therebetween.

First and second common electrodes 18a1 and 18b1 are formed between the second and third dielectric layers 14b and 14c from the bottom leaving a space therebetween within their common plane. The first and second common electrodes 18a1 and 18b1 face the first and second capacitor electrodes 16a and 16b, respectively, via the second dielectric layer 14b.

A first ground electrode 20a is formed between the third and fourth dielectric layers 14c and 14d from the bottom. This first ground electrode 20a faces to the first and second common electrodes 18a1 and 18b1 via the third dielectric layer 14c.

Third and fourth common electrodes 18a2 and 18b2 are formed between the fourth and fifth dielectric layers 14d and 14e from the

well as the second and fourth common electrodes 18b1 and 18b2 to be used as connecting terminals. Further, other external electrodes are connected with the first and second ground electrodes 20a and 20b to be used as ground terminals G.

A first capacitor C1 of a first LC resonator R1 is formed between the first and third common electrodes 18a1 and 18a2 and the first ground electrode 20a. A first inductor L1 of the first LC resonator R1 is formed by the first via hole 22a. Further, a second capacitor C2 of a second LC resonator R2 is formed between the second and fourth common electrodes 18b1 and 18b2 and the first ground electrode 20a and a second inductor L2 of the second LC resonator R2 is formed by the second via hole 22b. It is noted that because the first and second via holes 22a and 22b are electromagnetically coupled to each other, the inductors L1 and L2 are also electromagnetically coupled to each other. Further, a third capacitor C3 is formed between the first capacitor electrode 16a and the first common electrode 18a1 and a fourth capacitor C4 is formed between the second capacitor electrode 16b and the second common electrode 18b1.

Accordingly, the LC filter 10 shown in FIG. 1 has the equivalent circuit shown in FIG. 7.

In the LC filter 10 shown in FIG. 1, a sectional area of the inductor increases as compared to that of the prior art example shown in FIG. 8 because the first and second via holes 22a and 22b which penetrate through the plurality of laminated dielectric layers 14e,

electrode 18b2 and the second connecting electrode 26b, respectively. Further, third and fourth columnar via holes 22a2 and 22b2 which penetrate through the plurality of dielectric layers 14d, 14e, 14f and 14g in the thickness direction are created between the first ground electrode 20a and the first and second connecting electrodes 26a and 26b. These four via holes 22a1, 22b1, 22a2 and 22b2 act as inductor elements. It is noted that the third and fourth via holes 22a2 and 22b2 are electromagnetically coupled to each other.

While a number of external electrodes (not shown) which are used as the input/output terminals T1 and T2, connecting terminals and ground terminals G are formed on the side face of the laminate 12 in the embodiment shown in FIGs. 2 and 3 similar to the embodiment shown in FIG. 1, the external electrode used as the ground terminal G is connected only to the first ground electrode 20a.

Further, while each capacitor C1, C2, C3 and C4 are formed in the embodiment shown in FIGs. 2 and 3 similar to the embodiment shown in FIG. 1, the first inductor L1 of the first LC resonator R1 is formed by the via first and third holes 22a1 and 22a2 connected by the first connecting electrode 26a and the second inductor L2 of the second LC resonator R2 is formed by the second and fourth via holes 22b1 and 22b2 connected by the second connecting electrode 26b.

Accordingly, the LC filter 10 shown in FIGs. 2 and 3 also has the equivalent circuit shown in FIG. 7.

A sectional area of the inductor increases as compared to the prior art example shown in FIG. 8 also in the embodiment shown in

formed by laminating a number of dielectric layers 14a, 14b, 14c, ... or the like made out of a number of ceramic layers.

First and second common electrodes 18a1 and 18b1 are formed between the bottom dielectric layers 14a and 14b leaving a space therebetween.

First and second capacitor electrodes 16a and 16b are formed between the second and third dielectric layers 14b and 14c from the bottom leaving a space therebetween. These first and second capacitor electrodes 16a and 16b face to the first and second common electrodes 18a1 and 18b1, respectively, via the second dielectric layer 14b.

Third and fourth common electrodes 18a2 and 18b2 are formed between the third and fourth dielectric layers 14c and 14d from the bottom leaving a space therebetween. The third and fourth common electrodes 18a2 and 18b2 face to the first and second capacitor electrodes 16a and 16b, respectively, via the third dielectric layer 14c.

First and second ground electrodes 20a and 20b are formed between the fourth and fifth dielectric layers 14d and 14e from the bottom leaving a space therebetween. These ground electrodes 20a and 20b face the third and fourth common electrodes 18a2 and 18b2, respectively, via the fourth dielectric layer 14d.

Fifth and sixth common electrodes 18a3 and 18b3 are formed between the fifth and sixth dielectric layers 14e and 14f from the bottom leaving a space therebetween. These common electrodes 18a3

first and second capacitor electrodes 16a and 16b and are used as input/output terminals T1 and T2. Other external electrodes interconnect the first, third and fifth common electrodes 18a1, 18a2 and 18a3 as well as with the second, fourth and sixth common electrodes 18b1, 18b2 and 18b3 to be used as connecting terminals. Further, other external electrodes are connected with the first, second and third ground electrodes 20a, 20b and 20c to be used as ground terminals G.

A first capacitor C1 of one LC resonator R1 is formed among the third and fifth common electrodes 18a2, 18a3, and the first and third ground electrodes 20a, 20c and a first inductor L1 of the first LC resonator R1 is formed by the first via hole 22a. Further, a second capacitor C2 of a second LC resonator R2 is formed among the fourth and sixth common electrodes 18b2, 18b3 and the second and third ground electrodes 20b, 20c and a second inductor L2 of the second LC resonator R2 is formed by the second via hole 22b. It is noted that the first and second via holes 22a and 22b are electromagnetically coupled to each other. Further, a third capacitor C3 is formed among the first capacitor electrode 16a, the first and third common electrodes 18a1 and 18a2, and a fourth capacitor C4 is formed among the second capacitor electrode 16b and the second and fourth common electrodes 18b1 and 18b2.

Accordingly, the LC filter 10 shown in FIG. 5 also has the equivalent circuit shown in FIG. 7.

Although a conductor paste is thick-film printed on the ceramic green sheet to form the capacitor electrodes and the common electrodes in each embodiment described above, the capacitor electrodes and common electrodes may be formed by other known means.

It is also noted that the present invention may be applied to other electronic parts with built-in or integrally formed inductors such as an inductor containing only one inductor element and an LC resonator containing one inductor element and one capacitor, besides the LC filter containing two LC resonators in the exemplary embodiments and others.

Further, all the electrodes within the laminate including the pattern electrodes, capacitor electrodes, ground electrodes, connecting electrodes and common electrodes are made out of Ag and Cu for example in each embodiment described above. The electrodes may be formed also by baking a paste in which metal powder such as Ag and Cu and organic binder are blended.

Still more, the metal around the via hole and the metal of the capacitor electrodes and others may be the same material similar to the embodiments described above.

It is also noted that it is desirable to form the inductor of the inventive resonator only by use of the via hole.

While preferred embodiments have been described, variations thereto will occur to those skilled in the art and are within the scope of the present inventive concepts which are delineated by the following claims.

capacitor electrode connected to said inductor and disposed vertically to said inductor,

said plurality of resonators being disposed in the vicinity of said plurality of via holes and being electromagnetically coupled to each other.

7. An electronic part, comprising:

a plurality of laminated dielectric layers;

a plurality of inner electrodes, each of said inner electrodes being separated from an adjacent inner electrode by at least one of said plurality of said dielectric layers in the thickness direction thereof, wherein said inner electrodes and said dielectric layers form capacitors; and

an inductor formed by at least one a via hole penetrating through said plurality of laminated dielectric layers in the thickness direction thereof.

8. The electronic part of Claim 7, further comprising a plurality of external electrodes respectively connected to said plurality of inner electrodes, at least two of said external electrodes interconnecting at least two of said inner electrodes, and at least one of said external electrodes forming input terminals of said electronic part.

9. An inductor built-in electronic part substantially as hereinbefore described with reference to the accompanying drawings.

Application No:	GB 9615084.2	**Examiner:**	John Watt
Claims searched:	1 - 9	**Date of search:**	9 October 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H1R (RBB); H1T (T1C, T7C1B1, T7C1A, T12); H3U (UQF)

Int Cl (Ed.6): H01F 17/00, 17/04, 27/28, 41/04; H03H 1/00, 7/00, 7/09; H05K 1/00

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0512718 A1	(AT&T) see figures 14, 15, 29 & 30 and line 24, col.10 to line 11, col.11	1, 3, 5, 6 and 7 at least
X	EP 0311418 A2	(TDK) see figures 1-9 and lines 37-41, col.5	1, 3, 5, 6 and 7 at least
X	EP 0134556 A1	(TDK) see figures 1-6	1, 3, 5, 6 and 7 at least
X	WO 94/22281 A1	(FUJITSU) see figures 6-13 and 19	1, 3, 5, 6 and 7 at least
X	US 5055816	(MOTOROLA) see whole document	1, 3, 5, 6 and 7 at least

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